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ENERGY SPECTRUM LEVELS OF THE THUMPER TRANSDUCER.(U)
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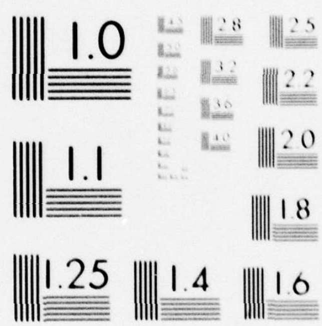

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

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ENERGY SPECTRUM LEVELS OF THE THUMPER TRANSDUCER*†

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by

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An impulse type acoustic transducer to be operated as deep as 10,000 ft is a particular need for some of our experiments. The "thumper" source (on loan from WHOI) appears to be worth looking into for this application.[1]

12 14 p. 15 Nonr-266(84)

In this connection I have done some calculations of energy spectrum levels as a function of frequency. The basic data available for this purpose is in the form of three photographs of a CRO presentation of the thumper pulses received by a hydrophone 6 ft below the transducer. This data[e] is reproduced ~~in Fig. 1A~~.[e] The main thump pulse is most clear in the lower tracing designated by the time scale "0.5 millisecond/square," and looks somewhat like a "bell" pulse whose width is about one half millisecond.

In order to compute the spectrum of the main pulse, it has been measured and approximated by curve fitting~~, as shown in Fig. 1B~~.[e] The spectrum of the pulse is computed by taking its Fourier transform.[2]

9 Technical memo.

*Columbia University, Hudson Laboratories Technical Memorandum No. 63, March 6, 1962.

†This work was supported by the Office of Naval Research under Contract Nonr-266(84).

[1] J. B. Hersey, H. E. Edgerton, S. O. Raymond, and G. Hayward, "Sonar uses in oceanography," Conference Preprint 21-60, Instrument Society of America, 1-9 (1960).

[2] See Appendix A for the details.

FIG. 1A —— PRELIMINARY DATA

EG&G Type ST-8 Sonar Thumper

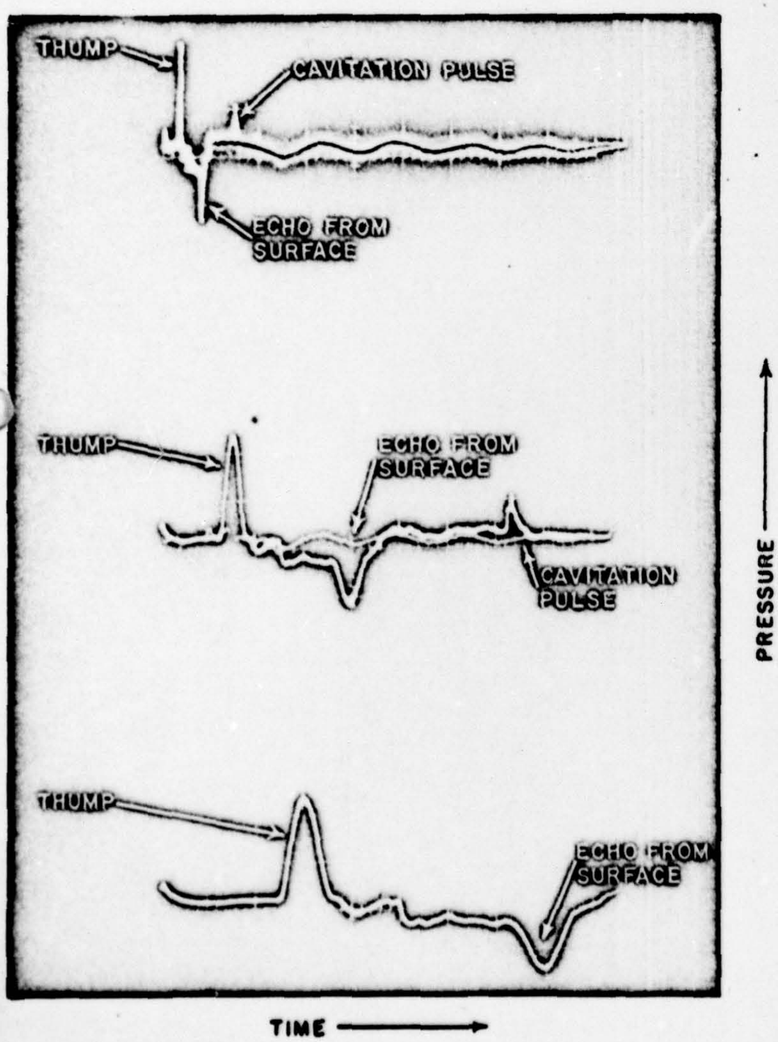
EG&G Type 2370 transducer No. 1, 4,000 volts C = 160 mfd.

Transducer 6 ft. below surface facing down.

Hydrophone, serial No. 100, Type BC 32 (Atlantic Res. Corp.) total capacity with 100 ft. of cable = .019 mfd, positioned 6 ft. below transducer.

Y deflection = 0.2 volts/square.

Peak pressure at 3 ft. is calculated to be about 0.5×10^6 dynes/cm^2.



5 milliseconds/square

1 millisecond /square

0.5 millisecond /square

Made on the Atlantis, January 18, 1960 by Dr. J.B. Hersey and Gary Hayward.

EDGERTON, GERMESHAUSEN & GRIER, INC.

BOSTON, MASS. LAS VEGAS, NEV.

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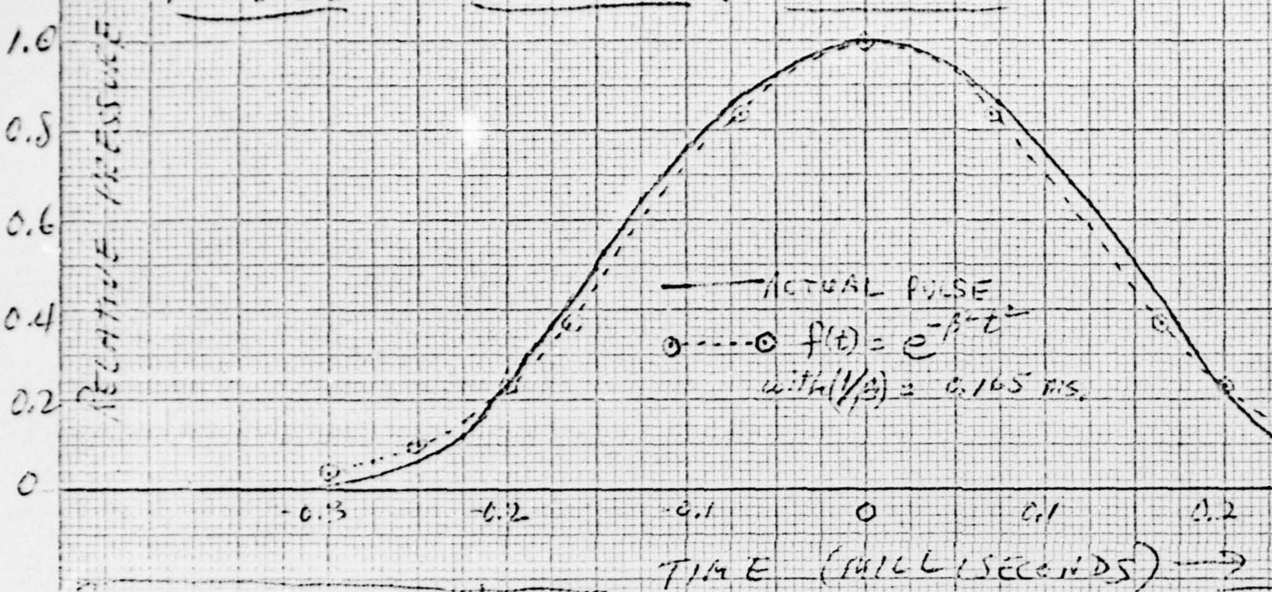
FIG. 1B — THUMPER PULSE



EG #6 DATA
Peak Pressure at 1 yard is calculated to be about 0.5×10^6 dynes/cm²

Transducer 6 ft. below surface facing down.

Transd. No. 1 4000 Volts
$C = 160$ mfd.

COMPUTATION OF SPECTRUM OF PULSE

$$S(\omega) = \int_{-\infty}^{+\infty} e^{j\omega t} e^{-\beta^2 t^2}\, dt = e^{-\frac{\omega^2}{4\beta^2}} \int_{-\infty}^{+\infty} e^{-\left(\beta t + \frac{j\omega}{2\beta}\right)^2} dt = \frac{2e^{-\frac{\omega^2}{4\beta^2}}}{\beta} \int_0^{\infty} e^{-x^2} dx$$

$$S(\omega) = \frac{\sqrt{\pi}}{\beta} e^{-\frac{\omega^2}{4\beta^2}}$$

Energy stored in capacitors is given by

$$W = \frac{CE^2}{2} = \frac{(160 \times 10^{-6})(4000)^2}{2} = 1280$$ watt-seconds or joules

Figure 2 is a plot of the relative spectrum and shows that the main thump has most of its energy in the frequencies between 20 and 1000 cps. The two broken line plots show how an increase in the width of the main pulse would improve the efficiency at the lowest frequencies. This result is obtained by adjusting the peak pressure so as to keep the total energy constant. Then we see that a doubling of the present thumper pulse width leads to a change in the useful low-frequency band from the original 20-1000 cps to 20-700 cps and a doubling of the energy per cycle, even though the peak pressure has been reduced by the factor $\frac{\sqrt{2}}{2}$ in order to keep the same total energy. If the thumper pulse width is made four times as long, the useful low-frequency band becomes 20-500 cps, and the low-frequency energy per cycle is four times as large.

In addition to the main thump pulse there is a damped oscillation which appears to be characteristic of the thumper source itself. Here again a curve was fitted to the data for calculation of the spectrum.[2] The actual energy spectrum levels in units of ergs/cm^2/cycle are shown in Fig. 3. For comparison purposes the energy spectra of the main thump pulse and a blasting cap or detonator are also shown.[3] It is clear that the thumper is an extremely weak sound source in comparison with the detonator of 0.002 lb. It is also obvious in Fig. 3 that the main thump would be submerged by the 123-cps oscillation on recordings restricted to the frequency band from about 90 to 150 cps.

In order to get some idea of the useful range of the thumper source, its pressure level spectrum at 10 kiloyards has been computed. This re-

[3]See Appendix B for details of calculation.

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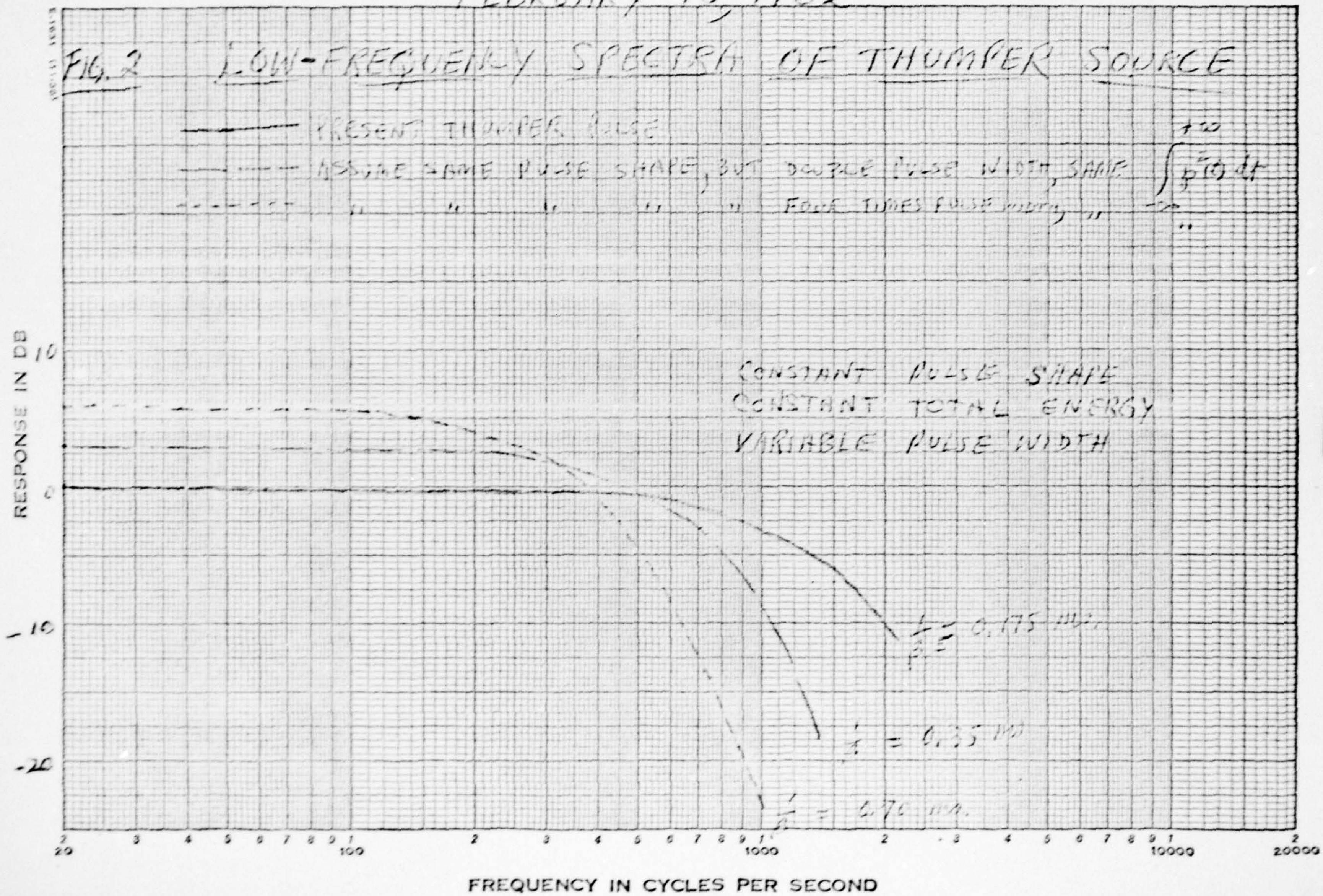
FEBRUARY 13, 1962



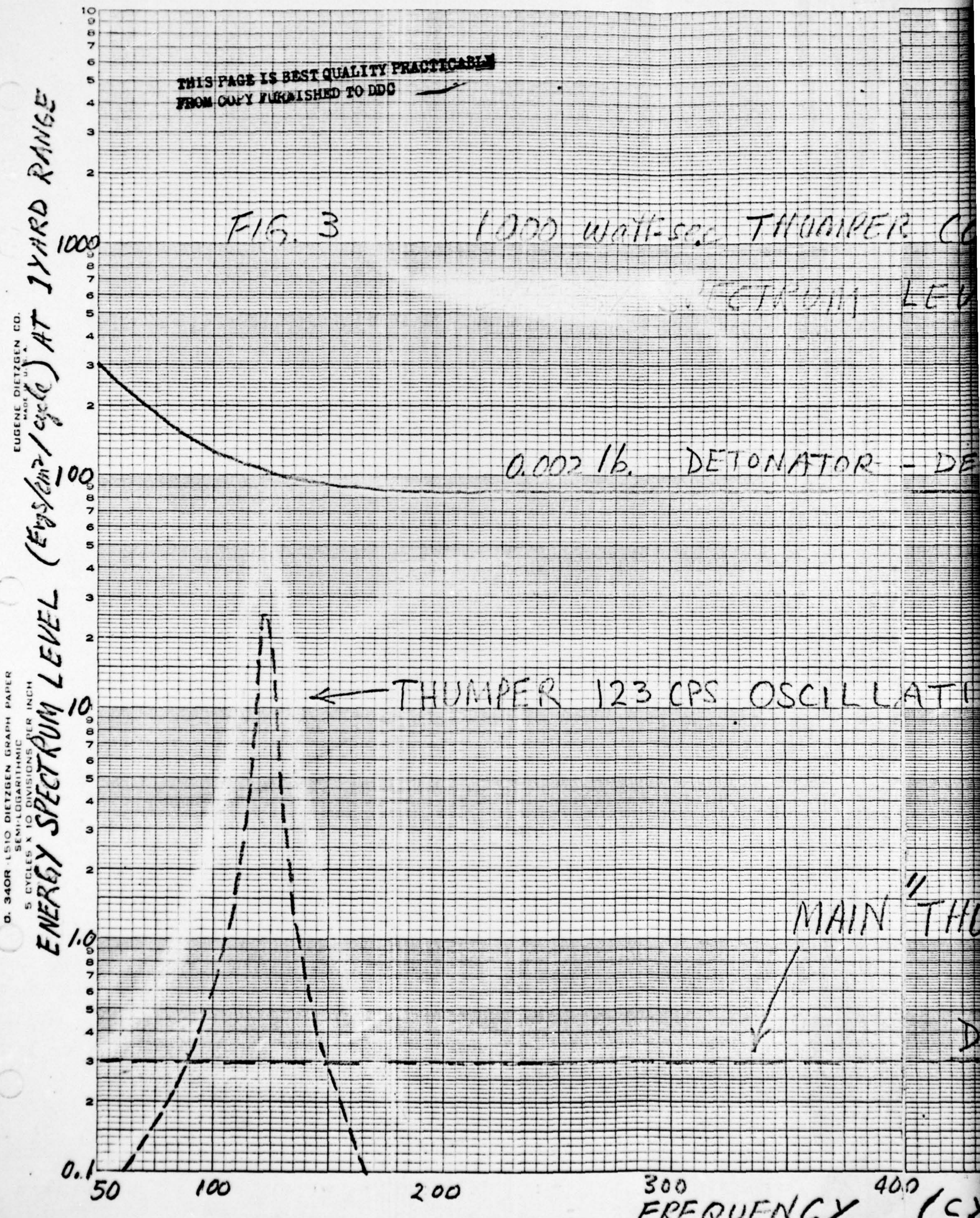
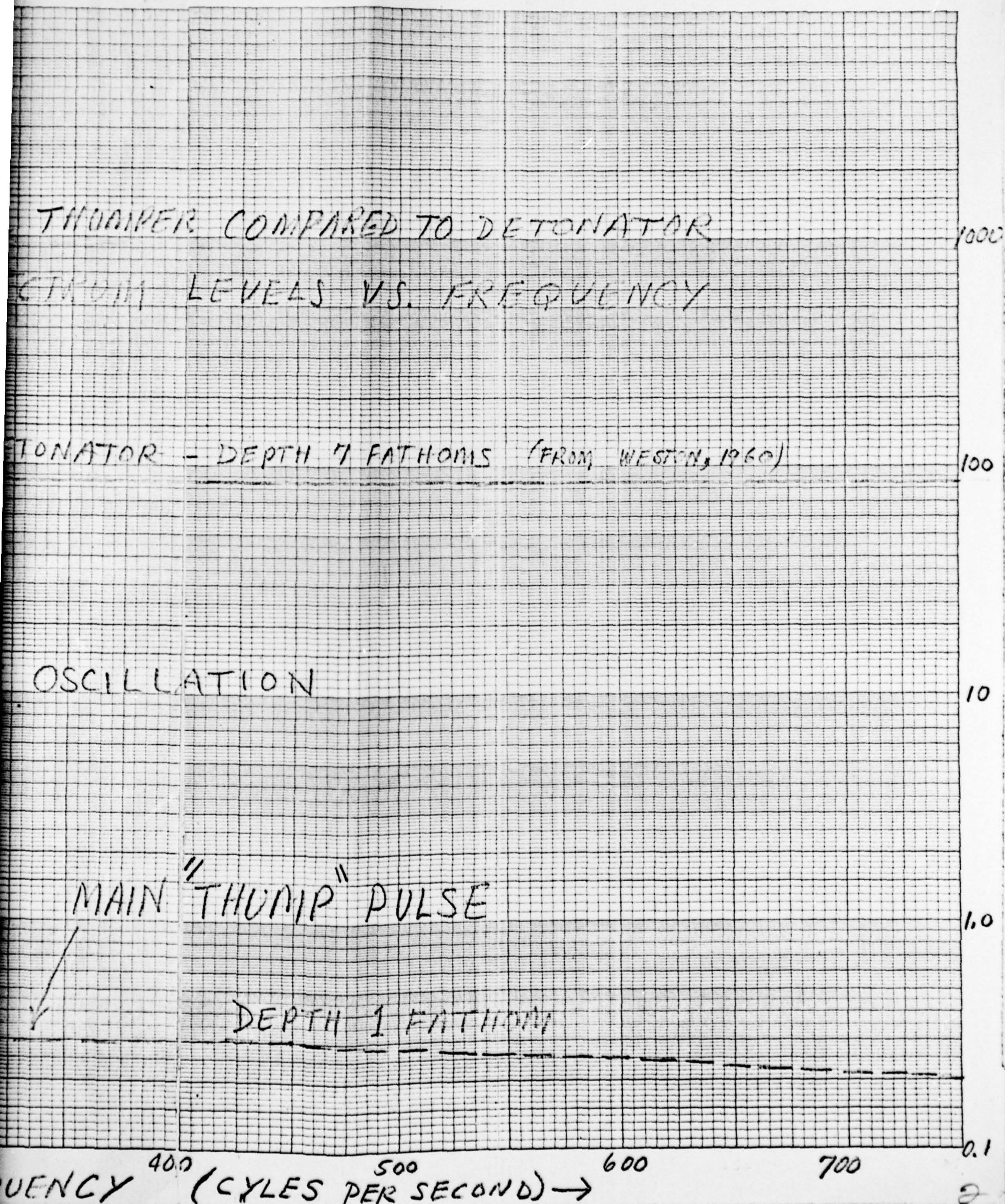


FIG. 3
1000 watt-sec THUMPER C
SPECTRUM LEV
0.002 lb. DETONATOR - DE
THUMPER 123 CPS OSCILLAT
MAIN "TH
D
ENERGY SPECTRUM LEVEL (Ergs/cm²/cycle) AT 1 YARD RANGE
1000
100
10
1.0
0.1
50
100
200
300
400
FREQUENCY (C
D. 340R-L510 DIETZGEN GRAPH PAPER
SEMI-LOGARITHMIC
5 CYCLES X 10 DIVISIONS PER INCH
EUGENE DIETZGEN CO.
MADE IN U.S.A.


THUMPER COMPARED TO DETONATOR
CTRUM LEVELS VS. FREQUENCY
TONATOR - DEPTH 7 FATHOMS (FROM WESTON, 1960)
OSCILLATION
MAIN "THUMP" PULSE
DEPTH 1 FATHOM
1000
100
10
1.0
0.1
400
500
600
700
UENCY (CYLES PER SECOND) →

sult is compared to Knudsen's[4] ambient noise curves in Fig. 4. We can conclude from this that for sea state one the thumper can be used up to ranges of about 5 miles, but the energy in the band from about 150 to 300 cps will be submerged in ambient noise.

There are several important conclusions that are suggested in the above results. First, we can get improved efficiency in the interesting band of frequencies between about 150 and 500 cps by increasing the thump pulse width by a factor of 2 or 4. Second, a considerable amount of energy may be gained for the thump pulse by eliminating the thumper plate oscillation. This might be accomplished by using a thicker and, therefore, more rigid plate.

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[4] V. O. Knudsen, R. S. Alford, and J. W. Emling, J. Marine Research 7, 410-429 (1948).

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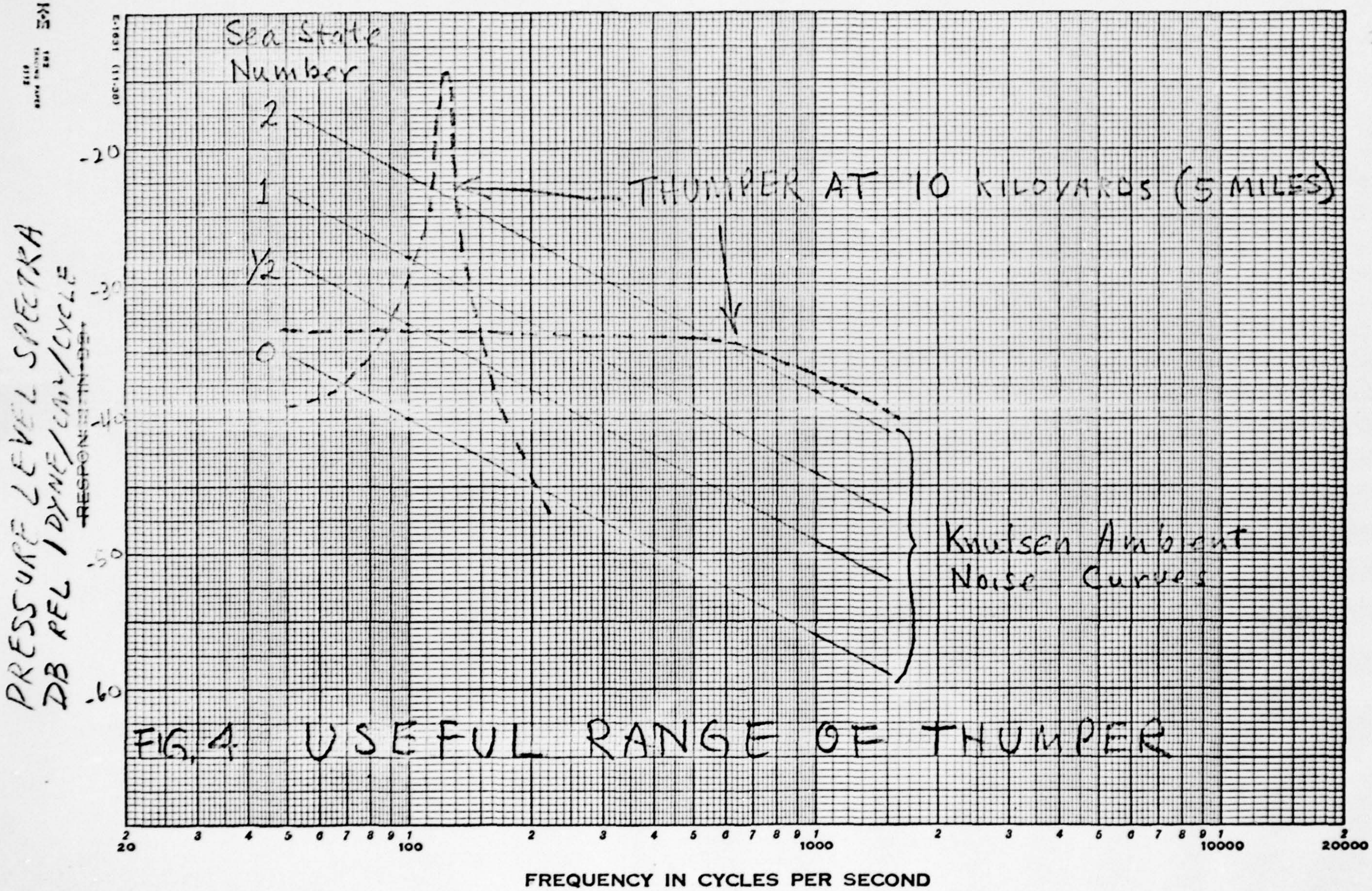

FIG. 4 USEFUL RANGE OF THUMPER

APPENDIX A

Spectra of Pulses

Assume a sound pulse of the form

$$p(t) = p_o \; e^{-\beta^2 t^2} = \frac{1}{2\pi} \int_{-\infty}^{\infty} S(\omega) e^{j\omega t} d\omega \quad .$$

The Fourier transform of $p(t)$ is

$$S(\omega) = p_o \int_{-\infty}^{+\infty} e^{-\beta^2 t^2} e^{-j\omega t} dt = p_o e^{-\frac{\omega^2}{4\beta^2}} \int_{-\infty}^{+\infty} e^{-(\beta^2 t^2 + j\omega t - \frac{\omega^2}{4\beta^2})} dt$$

$$= \frac{p_o}{\beta} e^{-\frac{\omega^2}{4\beta^2}} \int_{-\infty}^{+\infty} e^{-(\beta t + j\frac{\omega}{2\beta})^2} \beta dt = \frac{2p_o}{\beta} e^{-\frac{\omega^2}{4\beta^2}} \int_0^{\infty} e^{-x^2} dx$$

$$= \frac{\sqrt{\pi}\; p_o}{\beta} e^{-\frac{\omega^2}{4\beta^2}} \quad .$$

The relative spectrum of Fig. 2 was obtained by normalizing, i. e., dividing by $\frac{\sqrt{\pi}\; p_o}{\beta}$, and taking 20 times the logarithm of this quantity.

This procedure can also be applied to the damped oscillation

$$p(t) = \begin{cases} p_o e^{-at} \sin \omega_1 t & \text{for } t > 0 \\ 0 & \text{for } t \leq 0 \end{cases}$$

In this case the Fourier transform is

$$S(\omega) = p_o \int_0^\infty (e^{-at} \sin \omega_1 t)\, e^{-j\omega t} dt = p_o \int_0^\infty \frac{e^{-at} \left\{ e^{j\omega_1 t} - e^{-j\omega_1 t} \right\}}{2j} \, e^{-j\omega t} dt$$

$$= \frac{p_o}{2j} \int_0^\infty \frac{e^{-(a + j\omega + j\omega_1)t} dt}{2j} - \frac{p_o}{2j} \int_0^\infty \frac{e^{-(a + j\omega - j\omega_1)t} dt}{2j}$$

$$= \frac{p_o}{2j} \left[\frac{1}{a + j(\omega + \omega_1)} - \frac{1}{a + j(\omega - \omega_1)} \right] = \frac{p_o \omega_1}{a^2 - \omega^2 + \omega_1^2 + 2ja\omega}$$

APPENDIX B

Energy Spectrum Levels

If an acoustic pressure pulse $p(t)$ has a Fourier transform $S(\omega)$, then the energy spectrum level $E(\omega)$ is defined by the following relationship:

$$\int_0^{\infty} E(\omega)\, d\omega = \frac{1}{\rho c} \int_{-\infty}^{\infty} p(t)^2 dt = \frac{1}{\rho c} \int_{-\infty}^{\infty} \frac{|S(\omega)|^2}{2\pi} d\omega \, ,$$

where

$$\rho = \text{density}$$

and

$$c = \text{speed of sound} \, .$$

Then we see that the energy spectrum level is

$$E(\omega) = \frac{|S(\omega)|^2}{2\pi\rho c} \, .$$

The thump energy spectrum level is, therefore,

$$E(\omega) = \frac{1}{2} \frac{p_o^2}{\rho c \beta^2} e^{\frac{-\omega^2}{2\beta^2}} \, .$$

Similarly, the energy spectrum level of the damped oscillation is

$$E(\omega) = \frac{1}{2\pi} \frac{P_o^2}{\rho c} \frac{\omega_1^2}{(a^2 - \omega^2 + \omega_1^2)^2 + (2\, a\omega)^2}$$

These are the formulae used in constructing Fig. 3 for energy spectrum levels.